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Todd E. Marques

Rice University

Technical Report #80-13

August 1980

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Research Report Series

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Cognitive researchers have suggested that people encode the frequency attribute of items repeated in memory lists as an "automatic" by-product of their primary task (e.g. recall, recognition). Previous studies of our own, however, have questioned this automaticity for tasks of more realistic complexity. Therefore, the present series was carried out to clarify the role of active processing in frequency estimation

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(FE). Experiment 1 was simply a preliminary exercise designed to identify individuals with good time-sharing skills for use in subsequent studies. Experiment 2 used a "policy-capturing" approach to estimate the amount of importance attached by each subject to each dimension in an applicant-rating task. Under the assumption that the sheer amount of attention paid to each dimension should be roughly proportional to its perceived importance, the hypothesis was that FE performance should parallel dimensional weight. That it did not, and further, that overall FE performance was rather poor, suggested that frequency encoding in real-world tasks is in no sense "automatic". Moreover, sheer <u>amount</u> of attentive effort does not seem sufficient for the encoding of event frequency. Experiment 3 sought to determine whether the attentive effort must be invested in specific <u>kinds</u> of processing in order to produce better FE's. Here, a dual-task paradigm was used in which applicant rating and dimensional FE were both introduced at the outset as explicit and competing task requirements. If FE requires special effortful encoding processes, performance should improve at the expense of rating (and vice versa); if instead frequency information can be encoded "automatically", there should be no such trade-offs. The results clearly indicated the operation of mutual interference, suggesting that FE in realistic settings requires both attentive effort and the investment of that effort in specific encoding activities.

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INTRODUCTION

The ability to judge the frequency with which events occur appears to underlie human performance in a wide variety of cognitive tasks. Verbal discrimination learning (Ekstrand, Wallace & Underwood, 1966; Schmidt, 1978), the development of object and event classification systems (Rosch, 1978; Rosch, Simpson & Miller, 1976) attributions of causality (Kelly & Michela, 1980) and a host of human judgment tasks such as probability estimation, prediction and choice (Attneave, 1953; Estes, 1976a, 1976b; Howell & Burnett, 1978) all draw upon stored records of event occurrences.

Over the past 20 years, numerous studies have investigated sensitivity to frequency. Most have involved a common core of task demands; namely, subjects have been exposed to a series (or stream) of items (or events) and asked subsequently to recall the frequency with which a particular target item or set of targets appeared. There have been methodological options within the general frequency estimation (FE) paradigm that have differed according to the specific topic under investigation. These options may be classified into four broad dimensions. (a) Response requirement constitutes one of the most critical elements in frequency studies. The conventional responses have been absolute, relative and proportional frequency judgments. Absolute judgments demand a precise numerical estimate of the number of times a target appeared within a particular list or time frame. Relative and proportional judgments involve much cruder estimates. In the former case, the question is merely one of determining the more frequent of two (or more) targets, while the latter case involves a judgment of the ratio of target frequency to the total number of items within a particular list. (b) Stream characteristics have been manipulated extensively and have provided the basis for many inferences regarding the memorial representation of frequency. Critical stream characteristics include length, or the number of items per list, target distribution (i. e. massed vs. spaced), item pacing/ exposure duration, and dimensionality -- or the number of items presented simultaneously to the attending subject. (c) Stimulus characteristics are highly important variables in investigations of frequency sensitivity and yet have not been manipulated to the extent of the aforementioned dimensions. Typically, lists of simple verbal and non-verbal stimuli have been utilized, such as consonant-vowel-consonant strings (CVCs), 3-8 letter nouns, and single-and multiple-place digits. By contrast, some investigators have explored frequency sensitivity in a variety of more complex and realistic task and response domains such as the estimation of frequency for various causes of death (Lichtenstein, Slovic, Fischhoff, Layman & Combs, 1978) or particular characteristics of hypothetical applicant populations (Marques & Howell, Note 1). The role of stimulus characteristics will be elaborated later in this paper, particularly with reference to the automaticity of frequentistic information processing. (d) Pre-experimental instructions have been manipulated in attempts to distinguish automatic and control processes underlying the encoding of frequentistic information. Instructional manipulations generally have taken one of two forms: they have omitted any reference to an upcoming frequency estimation (FE) task, or they have misled subjects into anticipating a memory task other than FE, when, in fact, FE was ultimately required. The comparison of FE performance across different instructional conditions has led several researchers (e. g. Flexser & Bower, 1975; Hasher & Chromiak, 1977) to conclude that sensitivity to frequency is the result of an "automatic mechanism", and thus virtually free of attentional demands. This assertion has far-reaching implications that will be discussed later in the present paper.

Despite the extensive literature in the area of frequency sensitivity and the variety of experimental manipulations employed, the cognitive processes associated with the formation, use and revision of frequency records remain poorly understood. This failure is largely attributable to the fact that frequency sensitivity is extremely difficult, if not impossible, to study apart from basic memory/information processing operations such as encoding, storage and retrieval. For the most part, frequency investigations have been conducted and interpreted in the context of one or another of these operations thereby yielding an incomplete representation.

Representation of frequency in memory

One of the earliest theoretical accounts of frequency representation centers around the notion that trace strength is the key cognitive index of repetitiveness. According to this view, the trace of an event is strengthened with each successive event occurrence, and frequency information is derived by the gauging of trace strength. Obviously, the stronger the trace, the greater the frequency of the corresponding event is perceived to be. As Hintzman (1976) pointed out, the primary appeal of the strength hypothesis has been one of theoretical parsimony: that is, strength alone was thought to mediate recognition, recall and frequency estimation. Whatever additional popularity the hypothesis enjoyed may have been due to its consonance with the once prominent Hullian and Pavlovian accounts of learning that focused on such constructs as habit strength.

Early empirical investigations were basically supportive of the strength hypothesis. In one study, Erlick (1961) found perceived frequency of an event to be a simple logarithmic function of true frequency. Hintzman (1969, Experiment 1) presented subjects with lists of 3-letter nouns in which the frequencies of target words were 0, 1, 2, 4, 6 and 10. Subjects then provided frequency judgments which reflected a level of sensitivity comparable to that demonstrated by Erlick (1961). In fact, numerous studies involving a variety of experimental manipulations have produced similar findings. So pervasive is the finding that, in a review of the literature, Howell (1973a, p. 51) concluded "The main point of agreement in the experiments reviewed here is that subjects show a remarkable facility for synthesizing and storing the repetitive attribute of event occurrences." There is evidence, however, to suggest that this well-documented sensitivity is not the result of the straightforward representational process suggested by the strength hypothesis.

Erlick (1964) asked subjects to provide FEs based on lists containing 20, 40, 60, 120 or 240 items (the letters A & C) presented at a rate of four per second. Results included (a) a positive relationship between FE performance and item list length, (b) a general response bias with proportional FEs commonly in the range of 40-60%, irrespective of true frequency, (c) systematic underestimation of mid-to-high frequency item occurrences and overestimation of low-to-mid frequency occurrences, and yet (d) superior FE performance for extremely low (0-20%) and high (80-100%) frequencies. The strength hypothesis, in its most basic terms, cannot account for the systematic biases described here. Erlick (1961) also examined the relationship between target distribution and perceived frequency of two random sequential events, the letters S and N. When the frequency of the two letters was equated, the letter having the higher degree of clustering was judged to be more frequent. Using essentially the same paradigm, Hintzman (1969, Experiments 2 & 3) found the opposite relationship. Hintzman manipulated target spacing such that 0, 1, 2, 4, 8 or 16 items separated target repititions. Basically, he found the FEs were higher with increased target spacing. He argued that the spacing effect was due to the fact that contiguous, or nearly contiguous target repititions were not consolidated into long-term store (LTS). Thus, massed targets would not necessarily be perceived as distinct events and, therefore, subsequent FEs would not reflect the true frequency of target representation. Other investigators have reported findings consistent with Hintzman's when verbal targets (e. g. short nouns) were used (e. g. Radtke, Jacoby & Goedel, 1971). The fact that Erlick (1961) and Hintzman (1969) reported opposite findings may be indicative of differential processing strategies associated with verbal and non-verbal stimuli (Howell, 1973b).

Hintzman and Block (1970) entertained two hypotheses concerning the cause of the spacing effect: (a) the massing of targets results in a deficient memorial representation of frequency, (that is, consolidation failure), and (b) differential retrieval processes are associated with massed and spaced items. These investigators presented subjects with a series of 3-letter nouns in which the frequency of target spacing was either 0, 1 or 5 items. The subject sample was divided equally into two groups; one group was then given a standard absolute FE task and one group was asked to judge the number of times various targets appeared in succession (i. e. the length of a string of like target elements.) Results showed the familiar spacing effect for the FE task. More interesting was the finding that when asked to estimate the number of successive occurrences of a target, subjects were reasonably accurate. This, of course, suggests that the same information is stored for massed and spaced events and that the spacing effect is indeed due to differential retrieval processes. An important point to be made here is that none of the findings presented thus far is particularly damaging to the strength representation of frequency although certain conceptual refinements appear warranted. Even the differential FE performance for extreme target proportions (identified by Erlick) is managable. Consider the following scenario: a person types a word on a sheet of paper, but the ribbon is worn and so it is necessary to backspace and overstrike each of the letters until the desired darkness is achieved. No doubt, the first overstrike of the word would produce a marked increase in darkness. It is quite likely, however, that each successive overstrike of the word would result in less distinctive differences in darkness. That is, the typed impression is scarcely darker to the "naked eye" after 21 overstrikes than it is after 20 overstrikes. Yet, the difference between one and two overstrikes is readily discernable. Considering the typed words as metaphors for memory traces, the differential performance findings seem sensible. With few event impressions coded in memory, subsequent event repetitions are more pronounced, and therefore the gauging of event strength is more accurate. Thus, FE would be expected to decline as a function of list length, or "memory load." The somewhat paradoxical improvement in FE performance with the use of <u>extremely high</u> frequency events can be explained in basically the same terms as the low frequency case. Consider a list consisting of occurrences of two letters, S and N. If a subject is informend that he/she will be required to estimate the frequency of either letter it behooves the subject to track the less frequent event. If, for example, the letter S occurs 99% of the time and the letter N occurs 1% of the time, the precise number of N occurrences will be more accessible. This being the case, the subject should attend to the N item: if he/she is called upon to estimate the frequency of S, he/she has only to subtract the frequency of N from the total number of list items.

An alternative view to the strength hypothesis supposes that an event repetition is represented uniquely in memory in the form of a separate trace. According to this view, referred to as the multiple-trace hypothesis, frequency estimations are based upon the number of traces that can be retrieved for a particular event; the greater number of traces retrieved, the greater the perceived frequency. There has been considerable empirical support for this position.

Hintzman and Block (1971, Experiment 2) partitioned a 50-word list into 4 quadrants with 18 targets repeated in two different quadrants. The purpose was to determine if information about frequency and serial position of targets was represented separately in memory. One interpretation of a positive result would be that repetitive events are tagged independently and stored in the form of multiple-traces. Subjects were required to report the quadrant number in which the various target words appeared, and they were given the option of reporting two locations if they believed the words were repeated. In addition to the 18 experimental words or targets, several distractors were included as an index of "false-alarm rate." A 16% false alarm rate was reported, of these 14% were single presentation items and 2% were double presentation items. This compared with an overall hit rate of 86% for single and 98% for double presentation items. Separate ANOVAs were computed for first and second position judgments of repeated words. The results showed conclusively that target localization judgments were affected by the actual serial positions of the target within the list.

In Experiment 3, Hintzman and Block sought to demonstrate that memory for event repetitions included information about target frequencies from different event streams. After being exposed to standard memory-task instructions, subjects viewed two word lists that were separated by a 5-minute filler task. The subjects were not told in advance that they would be viewing two lists so as to avoid the possibility that mnemonic strategies would be developed to code the source of the target words. Four words were randomly assigned to each of the three repetition conditions, 0, 2 and 5 for either list. Following the presentation of the second list, subjects were asked to report the frequency with which the target words appeared in <u>both</u> lists. Mean judgments for the list/frequency level combinations were analyzed using multiple regression procedures. The true frequency of List 1 targets accounted for 89.6% of the response variability in List 1 and 10.2% of List 2 variance, while the corresponding figures for List 2 were 7.2% and 86.4%. Hintzman and Block have offered support for the multiple-trace representation of frequency by demonstrating a general sensitivity to the relative contribution of two sources to the overall frequency of a repetitive event. Were the frequentistic information for a particular type of event stored in the form of a unitary trace, such a sensitivity would be impossible.

Hintzman and Block have argued on the basis of the findings mentioned above that temporal and spatial "tags" operate to distinguish separate event repetitions. Howell (1970) also found that subjects are able to distinguish frequentistic and temporal properties of an event. Hintzman, Block and Summers (1975, Experiment 3) presented subjects with sequences of pictures that occurred either 1, 2 or 3 times at exposure durations of 2.2, 5.2 or 8.2 seconds and found that subjects were remarkably good at estimating frequency <u>and</u> duration of repetitive events. Furthermore, Hintzman, Block and Summers (1973) found that frequency judgments could be made easily in the case where the stimuli were received in more than one modality. Thus, Hintzman et al. (1973, 1975) appear to have documented the existence of temporal, spatial, modality and perhaps orthographic tags by which memory traces can be differentiated. In a broader sense, those data reinforce basic theoretical ideas about the nature of human memory. Bower (1967) and Underwood (1969), among others, have argued that an event is represented in storage by a collection of defining attributes. Underwood (1969) postulated the existence of several independent attributes: (a) temporal, (b) spatial, (c) modality, (d) associative - which are used to code contextual information relating to an event, (e) orthographic - which code structural or physical properties of events, and (f) frequency. There is, of course, considerable disagreement among investigators and theorists concerning the specific nature and function of the various trace attributes. The potential existence of the frequency attribute is especially controversial. The existence of such an attribute stands in contradiction to the multiple-trace representation in that it does not allow for multiple representations of events (Howell, 1973a). Contrary to Underwood's formulation, the bulk of the experimental evidence supports the notion that repetitions are stored separately in memory rather than in the form of a unitary multicomponent trace.

Another form of frequentistic representation has been referred to as numerical inference by Howell (1973a). Drawing on the work of Kaufman, Lord, Reese and Volkmann, (1949) and Shuford (1961), Howell suggested that individuals may store numerically-based impressions of event frequencies which are subject to"updates" based on the periodic counting of event samples. Similarly, Whitlow and Estes (1979) have argued that frequency estimates are based primarily on current or recent observations. This implies a differential weighting of current and historical evidence in the formation of frequentistic impressions (Marques & Howell, Note 1).

The fundamental distinction between multiple-trace and numerical inference representations of frequency lies in the intuitive data base. Recall that according to the multiple-trace view, FEs are derived from the retrieval of literal representations of distinct event occurrences, whereas the data base which forms the foundation of numerical inferences is non-literal, a collection of summary (or statistical) information concerning the stochastic properties of event streams.

Frequentistic retrieval processes

Ask an individual his/her age and an immediate and highly accurate response will be (or at least can be) obtained. Ask the same individual the number of times he/she has dined out with company in the past two weeks and the latency and perhaps even the accuracy of the response may differ markedly from the former question. Both questions involve the retrieval of repetitive events, birthdays in the former case, dinner engagements in the latter case. Yet the types of events are certain to be represented differently in storage. Consequently, different retrieval processes will be involved. For an individual to respond to a question concerning his/her age, he/she has only to assess or retrieve a single "number" and report it. This "number" is probably updated periodically (i. e. on each birthday anniversary) in much the same way that the previously described numerical inference processes operate. On the other hand, estimating the number of recent dinner engagements may require a variety of memorial search strategies, and even then the response may be "just a guess," particularly if the individual is under some time pressure to respond.

As Overton and Adolphson (1979) have argued, most investigations of frequency (esp. those concerning the multiple-trace hypothesis) have been concerned with the representational or structural form of frequency in memory; few investigations have focused on the cognitive processes associated with the retrieval of frequentistic information. The present section will address these processes with emphasis placed on memorial search options and mediating factors such as the "depth" of processing, "salience," "availability" and related concepts.

Radcliff (1978) has developed a tuning-fork metaphor for memory search in a recognition task. According to the model, the initiation of search for a target event or object invokes the search of adjacent locations in much the same way that the striking of a tuning fork elicits sympathetic vibrations in nearby tuning forks. For recognition memory, the search (or ringing) is terminated upon the location of a target. If the target is not located, retrieval is terminated after an exhaustive search. The same sorts of strategies may be involved in the retrieval of repetitive information. Reconsider the hypothetical question posed above concerning dinner engagements. When asked such a question, an individual will search memory for occasions in which dinner was eaten out. In this case, search will not terminate upon the first localization, rather it will continue until memory for the entire period of time (e. g. 2 weeks) in question has been sampled. This is a real-world example of exhaustive search. Were the question of dinner engagements changed to cover a period of two years rather than two weeks, very different retrieval operations would be expected. In the first place, the respondent probably would have neither the time nor the inclincation to recall the information for a two-year period. Secondly, as "common-sense" would dictate, it is unlikely that one would be able to make a precise judgment covering such an extended period of time. This suggests the use of memorial sampling strategies. Rather than attempting a day-by-day recollection of dining activities, it is possible to sample selected time periods and then derive a frequency estimate based upon some intuitive interpolation process.

Memorial search by sampling clearly entails strategies that are different from those suggested by the tuning-fork metaphor of Radcliff (1978). The most basic distinction lies in the controlling mechanisms of the search. Radcliff's search proceeds by assessing the contents of proximate storage locations. No assumptions are made about specific starting locations and termination is determined by the localization of target stimuli. By contrast, starting and stopping locations are determined more or less probabilistically in memorial sampling processes. Based on "hunches" the respondent scans or searches selected portions of memory. Returning again to the question of dinner engagements, if a person ordinarily dines out on Fridays, then a two-year scan of memory would be accomplished most rapidly by retrieving events pertaining exclusively to Friday evenings. Because the probability of a dinner out is higher for Fridays than other days of the week, this sampling procedure seems to be efficient. The point is that sampling procedures reduce cognitive processing of stored information and lead to substantially quicker responses. In some cases, these strategy-based responses may be more accurate as well. Performance tradeoffs between exhaustive and sampling search will be discussed later in the context of retrieval mediating factors.

Both the exhaustive and sampling search strategies are based upon the notion that repetitive events are stored as distinct memorial traces. As mentioned in the preceeding section on the memorial representation of frequency, this may not be true for all sorts of repetitive data. The third basic search process to be discussed is more consistent with the numerical inference representation. This process, not actually a "true" process, is one of <u>direct readout</u> of trace-strength, of numerical abstraction, or some related form. Here statistical information concerning repetitive information is retrieved. When queried, a 25-year old man will report immediately that he is 25 years old; he will not search his memory for birthday celebrations, refer to a calendar, subtract the year of his birth from the present year or anything of the sort....he simply will retrieve the number 25. Given that the intuitive data base is up-to-date and veridical, direct readout appears to be the most rapid and least error prone mode of frequentistic retrieval. Obviously, this mode of retrieval is only feasible for intuitive data bases that are accessed frequently and/or highly static in nature. Ask an individual the number of years since he graduated from high school and the response may begin with, "Let's see, I graduated in...." This, of course, is not direct readout. Ask a Naval "lifer" headed for retirement with 18 years of service how long he has been in the Navy and he will respond immediately; this is direct readout. For the Naval officer, years of service is a highly relevant consideration, and as such, it is likely to be maintained as a datum coded for direct access. Conversely, the elapsed time since high school graduation is seldom regarded as important, and therefore, direct access to the information would be of little value.

The fact that people are remarkably good at estimating the frequency with which events occur has been well documented (Hintzman, 1976; Howell, 1973b; Peterson & Beach, 1967). However, the quality of FE performance has not been uniformly high. In fact, it has differed, often markedly, from study to study. It is argued in the present paper that variability in FE performance is due in part to certain variables that mediate the retrieval of repetitive data. Characteristics of the stimuli are the major determinants of the mediation variables.

Clearly the outcome of any retrieval operation is dependent upon what information is stored; essentially, that which is not encoded cannot be retrieved. The "depth" or "elaboration" of stimulus processing at the time of encoding has been found to affect recall (e. g. Eysenck & Eysenck, 1979) and the magnitude of subsequent FEs (e. g. Goldman & Pellegrino, 1977; Rowe, 1974). Eysenck and Eysenck (1979) have equated _depth of processing_ with the extent to which semantic content and "meaningfulness" are extracted from a stimulus, while _elaboration of processing_ has been defined as the breadth and extent to which stimuli are processed, irrespective of the level or depth to which they are processed. In a discussion of the relationship between FE performance and depth of processing, Rowe (1974) concluded that repetitive events must be encoded at a semantic level, otherwise there would be no basis for the retrieval of frequentistic information. Rowe and Rose (1977) reported that FEs for target items in word lists were higher when subjects were required to rate the _imagery_ of all list items as they were presented. Although the findings of Goldman and Pellegrino (1977), Rowe (1974), Rowe & Rose (1977) and several others point to a pronounced effect of semantic processing on the development of easily-accessible frequency records, they do not suggest that semantic processing is indispensable.

Radtke, Jacoby and Goedel (1971) have demonstrated how the inclusion of non-semantic features can affect the development of frequency records. Subjects in the Radtke et al. study made relative FEs after viewing each of the eight experimental word lists. The study trials were presented for a period of 1.0 to 2.0 seconds, depending on the condition, and test trials were presented for 2.0 seconds. The more frequent alternatives in the test trial comparisons were either underlined at the time of their first occurrence in a study trial, at every occurrence within the study trials, or not at all. Underlining produced a substantial improvement in relative FE performance in the underlining conditions. Radtke et al concluded that the underlining of target repetitions enhanced retrieval through the provision of "retrieval cues." The effect of these cues was larger in the slow presentation (i. e. 1.0 sec.) condition. This was hypothesized to be the result of a combination of factors: an increased opportunity to rehearse coupled with increased <u>attentiveness</u> to the underscored items. While the investigators framed their findings primarily in terms of verbal discrimination learning, it is important to recognize the broader implications. Retrieval of frequentistic information is enhanced by verbal and non-verbal retrieval cues alike. Virtually any sort of distinguishing characteristic of an event will serve to increase the probability of its retrieval. The positive impact of extraordinary characteristics on recall and recognition is often referred to as the Von Restorff Effect (Crowder, 1976).

Mediating variables operate at perhaps a more active level in real-world or highly complex situations involving judgments of frequency, probability, choice, and so on. Tversky and Kahneman (1973) recognized the human propensity to use heuristics in making judgments based upon complex and/or extensive data. Through a series of empirical investigations, Tversky and Kahneman detected a strong reliance upon highly "sensational" or "memorable" information in decision making. This sort of information, for a variety of reasons alluded to earlier, is generally more accessible or available during retrieval operations. Apparently, the ease with which information can be retrieved or the "availability" of information constitutes an important heuristic for judging the frequency of event occurrence (Tversky & Kahneman, 1973). The utilization of this heuristic can lead to some rather distorted impressions of frequencies of real-world events.

In a recent series of studies, Lichtenstein, Slovic, Fishhoff, Layman and Combs (1978) investigated frequency judgments for lethal events. In Experiment 1, college students and members of a national women's group were asked to judge which one of a test pair (106 pairs in all) of lethal events was more frequent. In the pre-experimental instructions, subjects were told to:

> "Consider all the people now living in the United States -- children, adults, everyone. Now suppose we randomly picked just one of these people. Will that person more likely die next year from cause A or cause B? For example: Dying in a bicycle accident versus dying from an overdose of heroin. Death from each cause is remotely possible. Our question is, which of those two is the more likely cause of death?" (p. 554).

The subjects were also instructed to rate the relative likelihood of the two causes in terms of relative likelihood ratios (e. g. A is 100, 1,000 or 1 million times as likely as cause B).

Examination of relative FE and relative likelihood data revealed some striking inaccuracies in judgments provided by both subject samples. For example, subjects judged asthma deaths to be only slightly more frequent than deaths by botulism, when the true ratio was over 900:1. In general, subjects were more accurate in making relative FEs than they were in making likelihood judgments. Perhaps this was because the latter judgments called for a more precise assessment of frequency and, as Shanteau (1978) pointed out, the judgments were not based upon an actual experience with the data. Rather, the judgments were crude estimates made on the basis of indirect exposure from newspapers, television, personal communication and other media. At any rate, it is easy to see how indirect exposure to the repetitive data would result in less precise FEs. Also, the quality of frequency judgments was improved slightly when estimates were based upon relatively high-frequency causes of death.

In a subsequent study within this series, Lichtenstein et al (1978, Experiment 4) explored reasons for the gross misjudgments found in their previous investigations. In this experiment, the investigators sought to relate judgmental inaccuracies to (a) personal experiences with the various casues of death, either directly through near death or death of acquaintances or indirectly through the public media, (b) newspaper coverage -- statistical or day-to-day reporting of deaths, and (c) catastrophic ratings of the various causes of death -- the extent to which the events are massed or, in other words, the extent to which multiple deaths are involved. Using multiple regression procedures, Lichtenstein et al. determined that measures tapping availability (e. g. personal experiences, newspaper coverage, etc.) did an excellent job of predicting frequency judgments. In addition, a positive relationship was found between catastrophic ratings and judgmental errors, indicating a biasing effect of massed events which has been documented in the basic frequency literature (Hintzman, 1976).

In Experiment 5A, the investigators attempted to debias the subjects by instructing them to be aware of "uneven newspaper coverage, and the effects of imaginability and memorability" (p. 571). The debiasing instructions also informed subjects of the sources of inaccuracy detected in earlier studies; namely, an overreliance on direct and indirect encounters with the various causes of death, availability of memorability, publicity and so on. Not surprisingly, no effect of the debiasing instructions was detected. In Experiment 5B, debiasing instructions were augmented by the inclusion of specific illustrations of various biases and their impact on subsequent judgments. Again, no appreciable effect of debiasing instructions was found. These failures were probably due to the fact that whatever information the subjects used in forming their judgments was encoded and processed under the same sorts of biased conditions that were explored in the study. To instruct the subjects not to "count" such tainted information would severely restrict, if not eliminate all together, a suitable data base on which to formulate a decision. Alternatively, subjects may have lacked ability to recall the conditions under which the frequentistic data base developed; thus they were unable to differentiate biased and non-biased data.

The thrust of the Lichtenstein et al. series is on the influence of biasing factors and judgmental heuristics in the retrieval of frequentistic information. These studies provide numerous real-world examples of how these biases and heuristics mediate retrieval although the mediating variables explored by Lichtenstein and her colleagues are not confined to realistic response domains. Other investigations have also examined the use and measurement of these mediating variables in the laboratory (e. g. Beyth-Maron & Fishhoff, 1977). For example, Whitlow and Skaar (1979) explored the possibility that FEs are based on two sources of information: (a) the numerosity of an event or the number of independent occurrences of an event within a discrete temporal period (e. g. the number of fish caught on Saturday), and (b) episode frequency or the episodes in which some event occurred at least once (e. g. fish were caught on Saturday and Sunday). The basic idea is that overall frequency judgments should be based upon the combination of numerosities and episode frequencies. This is an intuitively appealing idea; if 12 fish are caught on Saturday, 15 fish on Sunday, then a total of 27 fish is caught over a week-end. Yet, Whitlow and Skaar have provided evidence which suggests that this alogorithm is not always applied in the derivation of FEs. Target events that typically occurred with high numerosity were judged to be more frequent than events which had actually occurred with greater total frequency but relatively low numerosities. The data reported by Whitlow and Skaar argue for the presence of a functional distinction between these "conceptually distinct" sources of repetitive information. Over reliance upon numerosities or episode frequencies appears to constitute another biasing factor that mediates the retrieval of veridical frequentistic information.

In the present section, several retrieval processes have been discussed. In addition, factors or variables that affect the efficacy of the processes have been reviewed. The particular retrieval operation or search strategy that is involved in a particular decision task is, of course, determined on the basis of a number of task and data-oriented variables. The frequency records of the years of one's life and the number of one's engagements are probably stored in very different manners. It follows that different retrieval strategies will be necessary to access these distinct representations, and with each strategy will come a peculiar set of variables that will mediate the success of retrieval.

A recurrent theme in the present paper has been that the ease and accuracy with which repetitive information is retrieved depends upon a number of factors: (a) the particular characteristics of the repetitive data which are encoded, (b) the representational form of the data in storage, and (c) the appropriateness of the retrieval operations invoked, considering factors (a) and (b). While it is clear that the formation and use of frequency records depend upon the interplay among encoding, storage and retrieval operations, it is the encoding operations, in particular, that are the primary determinants of what frequentistic information _can_ be stored and retrieved. Therefore, it is fitting that a section of the present paper be devoted to the discussion of frequentistic encoding operations.

Frequentistic encoding processes

In the previous section, FE performance was discussed in terms of retrieval and its mediating variables such as distinctiveness and availability. The fact that a particular event is "memorable" points to differential treatment at the time of encoding. Recall that according to the levels of processing account of memory, the depth (generally semantic vs. non-semantic) involved in encoding determines the likelihood that the stimulus will be retrieved subsequently (Eysenck & Eysench, 1979; Jacoby & Craik, 1979). Thus, the notions of memorability (or retrievability) and levels of processing are tied closely in the sense that the former is determined to a great extent by the latter.

There exists the possibility that memorability is a quality that applies to trace components rather than to the trace as a whole. As originally formulated, the notion of levels of processing centers around the idea that the trace comprises components that are selectively encoded on the basis of their relevance to a particular context (Craik & Lockhart, 1972). Essentially, the various components or dimensions that constitute a stimulus can be processed at differing levels; of course, the more relevant dimensions (in a particular context) receive more elaborate processing (Tyler, Hertel, McCallum & Ellis, 1979). This assumption forms a complex heuristic juncture among the information processing phenomena of selective attention, selective encoding, storage and retrieval. Moreover, it is argued that the ability to process stimulus components at different levels has broad implications for the encoding of frequentistic information.

How might the selective encoding of stimulus components (e. g. color, size, texture, semantic content) shape the development of frequency records? Consider the following example: Driver A is stopped in snarled traffic, staring blankly ahead at the flashing amber turn signal on the vehicle directly ahead. The left signal is flashing, and because left turns against a flood of oncoming traffic can delay motorists, Driver A is especially perturbed. The flashing signal has meaning; it warns of a turn, it means a substantial delay. Yet, it is quite unlikely that Driver A would be able to estimate accurately the number of flashes emitted by the signal during the time he spent staring at it. Now place Driver A in a psychologist's laboratory, seat him behind a cathode ray tube (rather than the wheel of a car), ask him to prepare for a standard memory task (rather than a delay in traffic), and then present a series of rectangular amber patches at a rate of two patches per second. The prediction is one of markedly improved performance when Driver A estimates the frequency with which the amber patches appeared. This scenario, however absurd, illustrates how context could operate to shape the development of frequency records through the selective encoding of stimulus components. When in traffic, the hypothetical Driver A may not even perceive the flashing signal as a repetitive event; it may be perceived as being "on" or "off" and only indicative of a motorist's intentions. In the laboratory setting, the instructions (or task orientation) and the general context probably would <u>dictate</u> a very different perception of the rectangular amber patches. Here the repetitive nature of the stimulus may be salient and, from the perspective of Driver A, warrant the investment of attentive effort.

Of course, the impact of attentive effort on the development of frequency records depends on the nature of the frequency encoding mechanism(s). There are two fundamentally distinct views of frequentistic encoding. First, a number of investigators (e. g. Hasher & Zacks, 1979) have viewed the encoding of frequency information as automatic as a direct by-product of the more generalized processes where sensory inputs are coded and stored in the form of multi-component traces. The second view is that frequency records are the products of special active processing strategies that draw upon a limited pool of cognitive resources (e. g. Marques & Howell, Note 1). Obviously, the resolution of the question of automaticity in frequency encoding is essential for furthering knowledge of frequentistic information processing.

Before reviewing the literature that bears directly on the issue of automaticity in frequency encoding, it is necessary to distinguish between automatic and non-automatic cognitive processes. There has been some variability among investigators on what constitutes automatic processes; however, a number of defining characteristics have appeared consistently: (a) a minimal requirement of attentional capacity, (b) the processes do not interfere with other ongoing mental operations and thus several automatic processes can operate in parallel, (c) processes operate without intent or conscious awareness, and (d) they appear in young children and show little improvement with age. By contrast, non-automatic processes, also referred to as conscious (Posner & Snyder, 1975), controlled (Schneider & Shiffrin, 1977:

Shiffrin & Schneider, 1977), or <u>effortful</u> processes (Hasher & Zacks, 1979) have been characterized by (a) an often extensive utilization of attentional capacity, and (b) a fairly pronounced development improvement (Hasher & Zacks, 1979; Posner, 1978; Posner & Snyder, 1975; Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977).

Several studies have been conducted to determine whether the cognitive mechanisms associated with frequentistic information are automatic or effortful in nature. Howell (1973b) presented subjects with 10, 25, 50 or 80 item lists in which common nouns were presented 0, 1, 2, 4, 6 and 10 times. Half of the subjects was instructed to prepare for a free-recall memory task, and the other half was led to expect a FE task. After viewing the word lists, subjects were given tasks which were either consistent or inconsistent with what they had been led to expect on the basis of pre-experimental instructions. Thus, subjects were classified into four groups defined by the content of the pre-experimental instructions (i. e. <u>cueing</u> for free-recall vs. FE). Basically, Howell found that consonance between cueing and task conditions led to superior performance only when the experimental task did <u>not</u> lead to significant differences in subsequent FE task performance. The differential impact of task cueing on free-recall performance held across the four memory-load conditions (10, 25, 50 and 80 item lists). The failure to find significant differences between the cueing/task conditions of free-recall/FE and FE/FE was taken as an indication that frequentistic information was encoded and maintained automatically. A number of subsequent investigations have been supportive of Howell's interpretation.

Flexser and Bower (1975) also examined the effects of task cueing on frequency encoding. Subjects in each of two task instruction conditions were told they would be presented with a series of CVC strings, some of which would be repeated. In the non-explicit task information condition, subjects were also told to attend carefully to each item so that they would be prepared for a memory task which was to follow. In the explicit task information condition, subjects were informed that the memory task would be one of frequency judgment. Flexser and Bower did not obtain significant differences in FE performance between the two instructional conditions. FE performance was measured in terms of absolute frequency judgments and in terms of the correlation between true and estimated frequencies -- a measure known as the discrimination coefficient. It is interesting to note that four of the 10 original participants in the non-explicit condition were replaced because they anticipated the FE task. This casts some doubt upon the credibility of the instructional manipulation employed in this study. The problem of task credibility will be addressed more fully at a later point in the present section.

In continuing this same line of research, Hasher and Chromiak (1977) explored the interaction of pre-experimental instruction and subject maturity on the formation of frequency records. These investigations sought to determine the extent to which frequency encoding was subject to controlled processing. The documentation of a developmental trend and a positive effect of task cueing would point to the existence of conscious, effortful or controlled processing in the formation of frequency records. The lack of significant relationships could be construed as supportive evidence for the notion of automaticity in frequency. In the Hasher and Chromiak investigation, students in grades 2, 4, 5 and college viewed a 70-item list which consisted of simple nouns presented with frequencies of 0, 1, 2, 3 and 4. No significant differences in FE performance were found among the various levels of subject maturity. Despite the fact that developmental trends in the utilization of controlled processing have been documented in other contexts, such as in attention deployment skills (Lane, 1979), one could conclude on the basis of the Hasher and Chromiak findings that processes involved in frequency encoding do not change with age, and, therefore, may be automatic in nature. Using essentially the same stimuli and experimental paradigm, Hasher and Zacks (1979) have replicated the preceeding findings using 40 young people (ages 18 to 24) and 40 elderly people (ages 56 to 80) as the basis for the developmental comparison. The findings from the two Hasher investigations were not in total agreement however. Hasher and Chromiak reported a low magnitude (but statistically reliable) effect of task cueing. However, Hasher and Zacks did not find reliable differences between the two pre-instruction conditions. Clearly, the Hasher and Zacks finding is more in line with previous investigations of automaticity in frequency encoding (e. g. Flexser & Bower, 1975).

Howell (1973a) has pointed to the need to explore frequentistic information processing in a greater variety of task and response domains. Indeed, all of the published research on automaticity in frequency encoding and most research covering other topics in frequency encoding have employed highly artificial experimental stimuli. CVC strings, three to eight-letter nouns, random digits and assorted symbols are totally lacking in the "richness" or multidimensionality that characterizes repetitive events in the real world. Given the simplicity of the conventional stimuli and the various demand characteristics induced by laboratory investigations, it is quite likely that the instructional manipulations used in these studies were quite transparent from the perspective of the subject. Whether or not the subject is instructed to code frequency information, the first repetition of a simple stimulus (e. g. CVC string) is likely to stimulate the formation of some sort of proposition regarding the investigation's "true" nature or purpose. Anderson and Bower (1974) have suggested the existence of a <u>propositional encoding</u> mechanism which serves to channel attention toward relevant stimulus dimensions. Recall the hypothetical situation where Driver A views a flashing amber light in the context of snarled traffic, and a series of rectangular amber patches in the context of a psychologist's laboratory. It is easy to see how very different propositions about stimulus meaning can be derived from stimuli which are, objectively, quite similar in nature. Hintzman and Stern (1978) have shown, however, that the encoding of frequency information may be independent of context in some cases. The point is that it is extremely difficult to disguise the repetitive characteristics of the simplistic and highly artificial stimuli used in conventional explorations of frequency processes. In short, the disentanglement of automatic and controlled processes requires the development of an experimental environment where incidental and intentional learning conditions exist. While many of the studies reviewed thus far were conducted to provide incidental accounts of FE, it is doubtful that they have succeeded.

Marques and Howell (Note 1) have used a more realistic task scenario in their investigations of frequentistic information processing. In Experiment 4, subjects served as undergraduate admissions committee members in deciding upon a large number of hypothetical applicants who differed in terms of race, sex and performance on three standardized tests. Subjects were told that, in actual admissions decisions, applicant race and sex were attributes that received considerable attention, primarily for purposes of quotas, affirmative action programs, and so forth. Subjects were instructed to "pay particular attention" to the race and sex of candidates they chose to reject so they would be prepared to defend their decisions if called upon to do so. These instructions were reinforced by a subsequent statement which informed the subjects that performance as admissions committee members would be assessed solely on the basis of rating consistency and the ability to recall the race and sex of rejected applicants. After these instructions were imparted, subjects sorted the 80 applicants into piles labeled "accept" and "reject". Following the completion of the rating task, the subjects were given a FE task that entailed the retrieval of information on two cued variables (i. e. race and sex of rejected applicants) and two non-cued variables (i. e. race and sex of accepted applicants). Thus the experimental design consisted of a within subject comparison of two cueing conditions and two cued variables (race & sex). The levels of FE performance did not change as a function of the race and sex variables. There was, however, a large and statistically reliable difference between cued (mean error = 39.87%) and non-cued (mean error = 73.73%) FEs.

There are factors that should be considered in interpreting the findings of Marques and Howell. First, the experimental stimuli were not artificial. The cover story for the study alluded to an interest in undergraduate perceptions of and attitudes toward the undergraduate admissions process, and the experimental materials they received (i. e. the hypothetical profiles) adequately reflected the stated objectives of the study. Second, although the stimuli were repetitive in nature, repetition of events had no specific meaning to the subjects. To view an application which is the same or very similar to an earlier application is not the same as viewing a nonsense syllable for the second time. In other words, repetition or similarity among applications is a "natural" aspect of rating, ranking or sorting procedures and, as such, does not alert the subject to process frequentistic information more extensively than is dictated by the cover story and pre-experimental instructions. Marques and Howell have demonstrated that the intentional encoding of frequency information leads to the development of more accurate frequency records than can be achieved through some incidental encoding process. Clearly, this suggests that controlled, conscious or effortful processing _is_ associated with the development of veridical frequency records. Furthermore, the finding that "true" incidentally derived frequency records are poor in quality compliments the findings of others (e. g. Lichtenstein et al, 1978) who have obtained similar results when using complex, real-world stimuli.

It should be noted that poor performance on FE tasks has also been shown to result from faulty encoding of complex but highly artificial stimuli. For example, Yntema (1963) found that people were unable to track the frequency of events consisting of two or more abstract objects or symbols. Put simply, Yntema concluded that people have a low tolerance for random information, but that the ability to code and retrieve information about multidimensional arrays improves when the various dimensions (or components) are highly integrated.

Even on the basis of the limited number of studies reviewed in this section, it is clear that the encoding of frequentistic information is a far from straightforward operation. In the conventional task and response domains, the frequency mechanisms appear to be automatic in nature. Yet, the dismally simplistic and non-representative nature of the stimuli used in these studies makes generalizations of these findings to what people "really do" very unwise. With the introduction of more complex and realistic experimental environments has come a whole new array of concerns regarding the roles of automatic processes, controlled processes and the inevitable "intermediary" processes in the encoding of frequentistic information.

New directions for frequency investigations

The ability to respond to the frequency with which events occur is the result of a complex interaction between encoding and retrieval operations. There are processing options associated with each operation. The encoding of frequency information can be achieved by "counting" or "tagging" like occurrences or it can be achieved through a variety of elaboration and mnemonic techniques by which relevant event components or attributes are held in storage in a form conducive to frequentistic retrieval. Frequency information can be retrieved by accessing a "counter mechanism" or direct readout, by engaging in an exhaustive or self-determining search of storage, or by the systematic or random sampling of storage. Obviously, the efficacy of the options depends upon the specific representational form of the frequentistic data. To date, there has been very little evidence to suggest that frequency is represented uniquely in memory, either in the form of a distinct trace attribute or otherwise. Sensitivity to frequency appears to be the <u>result</u> of special controlled processes that, given the appropriate task/response demands, operate to isolate individual items or events which appear in the context of a list or stream of data.

Further investigations of frequency in realistic settings will probably lead to expansions in the perceived role of effortful processes. With this expansion will come an enhanced appreciation for the impact of attention control mechanisms on frequentistic information processing. <u>Attention control</u> refers to the ability to distribute cognitive resources in the performance of non-automatic mental activities. Attention control or attention allocation has been reviewed several times in recent years (e. g. Lane, in press; Navon & Gopher, 1979; Norman & Bobrow, 1975), so an extensive review is hardly necessary here. The basic idea behind attention control is that humans possess a limited amount of resources (Norman & Bobrow, 1975) or capacity (Kahneman, 1973) for conducting mental operations. According to Johnson and Heinz (1978) processing capacity can be defined as "the limited pool of energy, resources or fuel by which some cognitive operations are mobilized and maintained." (p. 422) It is important to recognize that some but not all cognitive operations draw from a limited pool of resources. Recall that one of the principal differences between automatic and controlled processes is that only the latter required limited cognitive resources. Memorial operations that require effortful or controlled processing include the use of imagery, rehearsal, organization and mnemonic strategies (Griffith, 1976; Hasher & Zacks, 1979). Add to the list frequency as it can involve any of these operations.

As suggested earlier, the primary advantage of automatic processing is that it is not "expensive" in terms of cognitive resources. It interferes only minimally with other ongoing controlled processes (which do require capacity). Yet, except for a few circumstances, the automatic coding of frequency is not advantageous. Is, for example, the frequency with which a trace consisting of attributes A, B, C, D and E maintained independently from the frequency of a trace consisting of A, B, C, D and F? Clearly this is not feasible; considering the complexity of stimuli encountered in the real world, an enormous number of independent counters would have to be maintained. There must be some mechanism by which to address traces without having to actually store the frequencies with which particular bundles or configurations of attributes appeared. Recall that there is evidence to suggest that people are capable of encoding stimulus attributes at differing levels and degrees of elaborateness (Jacoby & Craik, 1979). Decisions as to which attributes receive elaborated processing and how they are represented in storage appear to be under attentional control (Treisman, Sykes & Gelade, 1977).

Navon and Gopher (1979) have argued that utility is a powerful determinant in cognitive resource allocation or attentional control. Given a set of expectations about performance criteria, the nature of the task and stimuli, people will allocate their limited resources in such a way as to maximize performance (or utility rewards). This notion of utility applies equally well in the encoding and retrieval of frequentistic information. If the repetitive characteristics of an event stream have no importantce for an individual, he/she probably will not invest resources in tracking frequency. This is especially true when the resources could be expended more profitably by attending to relevant aspects of the event stream.

The possibility that utility-based controlled processes function in the coordination of frequentistic encoding, storage and retrieval operations warrants further consideration. First, however, the presence of controlled processes in frequency must be documented by empirical studies which offer unequivocal tests of the effects of incidental and intentional strategies on subsequent FE performance.

The series of experiments to be described was conducted to elucidate the role(s) of controlled processes in frequentistic operations.

In contrast to many earlier investigations of these processes (e. g. Hasher & Chromiak, 1977), the present series of experiments employed multidimensional stimuli that had some measure of real-world significance to the participants. Relatively complex and realistic stimuli, however hard to manage, will ultimately prove more useful in the delineation of the cognitive processes involved in real-world frequentistic information processing.

EXPERIMENT 1: CLASSIFICATION OF INDIVIDUAL SENSITIVITIES TO PAYOFFS

It now seems clear that in complex and realistic experimental environments, subjects do not simply "tag" or "count" the frequencies of like occurrences (Lichtenstein et al, 1978; Marques & Howell, Note 1). Special active processing is required to transform repetitive information into a form that is ammenable to frequentistic recovery (or retrieval). The question of interest here concerns the nature of these transformational processes. The hypothesis is, of course, that frequency encoding represents a conscious, controlled or effortful process.

One way to demonstrate that an operation is conscious is to show that an individual's performance level on that operation declines when he/she is saddled with additional capacity-demanding mental operations (Posner & Snyder, 1975). Reading and counting are two tasks which can be done by most individuals with relative ease. However, reading silently and counting aloud <u>simultaneously</u> can be extraordinarily difficult. The reason is that both operations compete for cognitive resources from the same limited pool. Inferences about the attentional demands of frequentistic information processing can also be drawn from this dual- or concurrent-task paradigm. Although such inferences must be drawn with extreme caution.

Assessment of the unique attentional demands posed by a frequency task can be difficult. First, as Kahneman (1973) has pointed out, the supplies of cognitive resources vary between <u>and</u> within individuals. While it is not surprising that some individuals would have greater cognitive resources than others, the notion that cognitive resources are allocated dynamically within an individual is a bit puzzling. According to Kahneman, there exists an "elastic capacity" for the containment of cognitive resources. Thus the supply may expand or contract depending on several task and subject variables. Second, it is well known that people are able to allocate, distribute or deploy cognitive resources in such a way as to perform satisfactorily in a number of dual-task situations (Lane, 1979, in press; Norman & Bobrow, 1975; Navon & Gopher, 1979). The problem is that individuals may differ markedly in the "ability" to <u>timeshare</u> or allocate cognitive resources. Before the attentional demands of frequency can be assessed, it is therefore necessary to control these obscuring factors.

The purpose of this first experiment was thus to classify individuals according to the ability to timeshare in a dual-task setting. In this experiment, timesharing ability was defined operationally in terms of subject responsiveness to a payoff scheme which was designed to induce tradeoffs in the distribution of attentive effort between two concurrent tasks. Clearly, the advantage to knowing the timesharing skills of prospective subjects lies in the ability to procure a sample of subjects in which the range of these skills is low, thereby eliminating individual differences in timesharing as an obscuring factor.

Method

<u>Subjects</u>. Thirty-two undergraduates (15 male and 17 female) from an introductory psychology course volunteered to participate in the

present study in exchange for extra credit.

Task. Subjects viewed profiles of hypothetical applicants for undergraduate admission who differed in terms of sex and performance on three standardized tests. Two tasks were devised that required the use of the profile information. Task A involved tracking the frequency of male applicants over sequences of 15 applications, while Task B involved the summation of the standardized test scores in each applicant profile. Effort on the concurrent tasks was controlled by a different payoff scheme in which the prescribed importance of "excellent performance" on Task A vs. Task B was 10/0, 7/3, 5/5, 3/7 and 0/10. Thus, for example, under the 5/5 payoff condition, performance on the two tasks was valued equally, whereas, in the 10/0 and 0/10 conditions, performance on only one task was consequential. The object of the task, as explained to the subjects, was to regulate effort in each of the tasks to the extent that was warranted on the basis of the assigned utilities. Subjects were informed that their overall performance would be measured in terms of their sensitivity to the utilities; that is, how well they were able to match Task A and Task B performance levels with the assigned utilities.

Stimuli. As demonstrated in Figure 1, the hypothetical applicant profiles were designed to facilitate the rapid encoding of applicants' sex (coded M or F), and the three quantified test scores. The range of scores and the degree of intercorrelation among scores were based upon the distrubutional characteristics of the actual Rice University applicant population. The frequency of male applicants within the

SEX	M
NMQT	109
SAT-V	610
SAT-Q	600

Figure 1. Illustration of an hypothetical applicant profile used in the performance of two tasks, tracking the frequency of male (M) applicants, and summing the three standardized test scores.

15-profile sequences was varied randomly over a range of 7 to 14. The midpoint of this range, 10.5, corresponded to the proportion of males in the actual Rice applicant population (i. e. 70%). The applicant profiles were typed on clear plastic film and affixed to 1,4 mm glass-less slidemounts. The profiles were presented using a Kodak Carousel projector, equipped with a Lafayette 43016 (US-IE) tachistoscopic shutter.

Procedure. Subjects were given instructions that elaborated the basic mechanics of dual-task investigations. Also, for illustrative purposes, they were asked to imagine themselves as pre-med students with two imminent final exams, one on biochemistry and the other on Spanish. They were then read the rhetorical question: "Given that you had prepared for neither test, and they were both the next day, how would you divide your mental effort in studying for both exams? Well, obviously, you would allocate the most effort, or try the hardest, to excell at the more important test. Because you are a pre-med major and your chances of acceptance in medical school are 'on the line,' you would choose to invest the most effort in studying biochemistry." An analogy was then drawn between timesharing efforts in studying for exams and distributing effort between Task A and Task B.

Each subject received an individualized response booklet. Every booklet consisted of 11 pages, one page for biographical data, and 10 pages for responses to the profile sequences. On each of these pages was a column of 15 blanks for recording responses to Task B (summation of the 3 test scores). At the bottom was an additional blank for the Task A (FE) response. The source of individualization in the booklets came from the assignment of task utilities which were coded in the upper-right-hand corner of the page. Performance payoffs were assigned randomly and independently for each subject so that each viewed identical applicant profiles yet processed the information under various payoff conditions. All payoff conditions (i. e. 10/0, 7/3, 5/5, 3/7 and 0/10) were represented in both the first and last five sequences in order to permit the calculation of two separate measures of sensitivity-to-payoffs (for reliability estimation purposes).

After the subjects, who met in groups of 5 to 15, were familiarized with the dual-task paradigm and all questions were entertained, the presentation of the stimulus materials began. The applicant profiles were presented via slide projector using timed exposures of 2.0 sec. per profile followed by a 6.0 sec. interval for a written Task B response. Task A responses were made during a 10.0 sec. interval which was inserted between successive 15-profile sequences. A short rest break of approximately 2 minutes was taken after the completion of sequence No. 5. Just prior to the initiation of each profile sequence, the subjects were encouraged to focus on and follow the payoff scheme printed at the top of their response forms.

Results and Discussion

Of the 32 subjects who participated in Experiment 1, 11 either failed to follow instructions, could not keep pace with the 2.0 exposures, or adopted strategies in which the quality of their responses was not commensurate with the expenditure of effort. The most common inappropriate strategy involved the summation of test scores (Task B) from the rightmost to leftmost digits. For example, in summing the scores 700, 650, 218 a subject (adding right to left) may only process two digits and make a response of 68. This is much farther from the correct answer of 1568 than a response based on only the addition of the leftmost digits, 1500, which probably required less effort and yet constituted a more rational approach to the estimation of large numbers. Data from the 11 exceptional cases were not analyzed, thereby leaving a usable sample of 21 individuals.

An initial step in the analysis was to convert the Task A and Task B response data from each sequence into estimation accuracy scores (EA) of the form:

$$EA = 100 - \left[((TV - E) \cdot 100) / TV\right] \qquad (1)$$

where TV = true value of the quantity being estimated (FE in Task A or summated score in Task B)

and E = estimate of TV provided by subject.

The quantity expressed in equation 1, whether applied to Task A or Task B performance, has the upper limit of 100 (which refers to perfect performance). For each of the 10 sequences, the 15 EA values representing the accuracy of Task B responses were converted to a single mean EA. Thus, 20 EA scores were used to code each subject's overall performance; that is, one EA-Task A and one EA-Task B score for each of the 10 sequences.

A measure of sensitivity-to-payoffs (STP) was then derived for each subject. This correlational measure consisted of:

$$STP = r_{PFR \cdot POR} \qquad (2)$$

where PFR = performance ratio, or the ratio of Task A and Task B EA values for a particular profile sequence.

and PDR = payoff ratio, or the ratio of utilities associated with Task A and Task B performance for a particular profile sequence.

This measure was computed separately for the first and last five sequence blocks. It is important to note that the STP values were not based on all five payoff conditions represented in each of the blocks. Only the performance data from the 7/3, 5/5 and 3/7 payoff conditions were used. The 10/0 and 0/10 conditions were not included in the measure because they did not require the allocation of attentive effort. In fact, these conditions were included as part of the payoff system primarily to provide subjects with anchors by which to gauge intermediate effort levels dictated by payoffs that did involved allocation.

The mean (and standard deviation) STP values obtained from the first and last five profile sequences were .549 (.569) and .529 (.454) respectively. The STP scores ranged from a low of .015 to a high of .999. In general, there was close agreement between the two STP measures obtained from each subject as indexed by the Pearson's r coefficient of .536 ($p < .01$) or .733 as indexed by the Spearman-Brown

Prophecy Formula (Weiner, 1971).

The fact that the STP measure proved reliable further justified its use as a measure for selecting subjects for subsequent experiments. It will be recalled that the main purpose of this study was to identify subjects demonstrably comparable in their sensitivity to timesharing manipulations.

Four subjects, two males and two females, were selected from among the entire sample of 21 prospective subjects for use in subsequent investigations. Both the magnitude and consistency of STP scores were used as criteria in the selection of the four subjects. The selected subjects' STP scores from each sequence block are reported in Table 1. From Table 1, it is evident that the sample of subjects selected for use in Experiment 2 and Experiment 3 were well matched in the ability to regulate task performance in accordance with instructional demands.

TABLE 1

Selected subjects' STP scores obtained from the first and last five-block sequences together with measure means and standard deviations

	STP Score	
Subject	Block #1	Block #2
1 (F)	.976	.999
2 (M)	.946	.887
3 (M)	.913	.916
4 (F)	.906	.934
Mean	.935	.934
SD	.032	.048

Note: F = female; M = male

EXPERIMENT 2: EVIDENCE REGARDING THE SUFFICIENCY OF ATTENTION IN FREQUENCY ENCODING

This experiment was undertaken as an initial step toward the elucidation of the role(s) of attention-control processes in the formation and use of frequency records. It has been demonstrated by Hasher and Chromiak (1977), using verbal stimuli, and by Marques and Howell (Note 1), using realistic multidimensional stimuli, that pre-experimental instructions (or task-cueing) affect the development of frequency records. Presumably these effects reflect the direction of attention to the repetitive characteristics of the stimuli being processed. Thus, it appears that attention is a *necessary* condition for the development of veridical frequency records.

The central question addressed in Experiment 2 concerned the *sufficiency* of attention. The view that sensitivity to frequency is the result of non-strategic processing (e. g. Flexser & Bower, 1975; Hasher & Zacks, 1979) would gain considerable credibility if it were found that the mere investment of attention in repetitive data is both a necessary *and* a sufficient condition for the encoding of frequency. If, on the other hand, attention were necessary *but* not sufficient, one would have to assume that a particular kind of effortful processing is required; that attention must be invested in specific encoding activities or strategies (special effortful processing).

A complex rating task was used to test the hypothesis that special effortful processing of repetitive information is required to form reasonably accurate frequency recrds. The task involved the rating of a large number of hypothetical candidates who differed in several evaluative dimensions. The subjects were free to aggregate the information in any consistent manner that seemed appropriate. The consistent aggregation of the evaluative cues was presumed to involve the investment of effortful processing. The question was whether the encoding of frequency information would be an incidental by-product of the effortful processing associated with the rating task. Clearly, a negative outcome would suggest that special effortful processing is required.

Method

Subjects. Four subjects (2 male and 2 female), recruited initially for participation in Experiment 1, were invited back to participate in this experiment. The subjects were paid $5.00 per hour for the pre-experimental and experimental sessions which lasted 1 hour and 3 hours respectively.

Task. The subjects rated large groups of hypothetical applicant profiles in terms of suitability for five different positions: oil-field worker, graduate student, secretary, professional boxer and fashion model. All profiles consisted of seven evaluative dimensions (cues) which, of course, differed according to the particular position for which the selections were made. The evaluative dimensions for each of the positions are shown in Table 2. As shown in Table 2, three dimensions (general intelligence, physical strength and physical attractiveness) appeared in all five of the profile types. These dimensions differ markedly in relevance to the various positions and were included to ensure that subjects would "pay attention" to some dimensions while "ignoring" others in each profile type.

The subjects were told that the primary intent of this investigation was to find out how individuals formulate "consistent and conscientious" applicant rating policies. They were instructed to be concerned with the development and consistant application of a policy best suited for the particular position under consideration. Subjects were also informed that they would be required to estimate the absolute frequency with which the hypothetical applicants were "low" on the various dimensions (e. g. how many graduate student applicants were low in general intelligence?) after the evaluation of each profile set. Pre-experimental instructions accentuated the facts that the FE estimation task was considered to be of secondary importance and that subjects should not be distracted from the primary task of profile evaluation.

Stimuli. The hypothetical applicant profiles were printed on unlined, continuous forms with two profiles per page. Subjects reviewed 78 applicant profiles for each of the five positions. Like the stimuli used in Experiment 1, the applicant data were arranged to facilitate rapid encoding. The actual appearance of the profiles is shown in Figure 2. As shown, the value of each profile dimension was dichotomized (i. e. Hi vs. Lo). The actual values assigned to the dimensions were determined by a Fortran routine. Essentially, the routine generated a 7 (number of cues) X 78 (number of profiles) matrix of deviates in the range of 0 to 1 for each applicant set. The deviates were generated such that their converstion to integer values

TABLE 2

Evaluative Dimensions (Cues) Associated With the Five Positions for Which the Hypothetical Applicants Were Evaluated

OILFIELD WORKER

1. Experience with high pressure pumps and valves
2. Experience with heavy oilfield machinery
3. Mechanical/spatial aptitude
4. Physical attractiveness
5. General intelligence
6. Hand-eye-foot coordination
7. Physical strength and endurance

GRADUATE STUDENT

1. Physical strength and endurance
2. General intelligence
3. Physical attractiveness
4. Letters of recommendation
5. Motivation level
6. College GPA
7. Emotional maturity

SECRETARY

1. Physical attractiveness
2. Ability to take and transcribe dictation
3. Writing skills
4. Proficiency with office machines
5. Bookkeeping skills
6. Physical strength
7. General intelligence

TABLE 2 (cont'd)

Evaluative Dimensions (Cues) Associated With the Five Positions for Which the Hypothetical Applicants Were Evaluated

PROFESSIONAL BOXER

1. Quickness of feet
2. Physical strength
3. Quickness of hands
4. General intelligence
5. Tolerance for pain
6. Physical attractiveness
7. Number of career injuries

FASHION MODEL

1. Photogenic appeal
2. Physical attractiveness
3. General intelligence
4. Physical strength
5. Social skills/gregariousness
6. Acting experience
7. Youthfulness of appearance

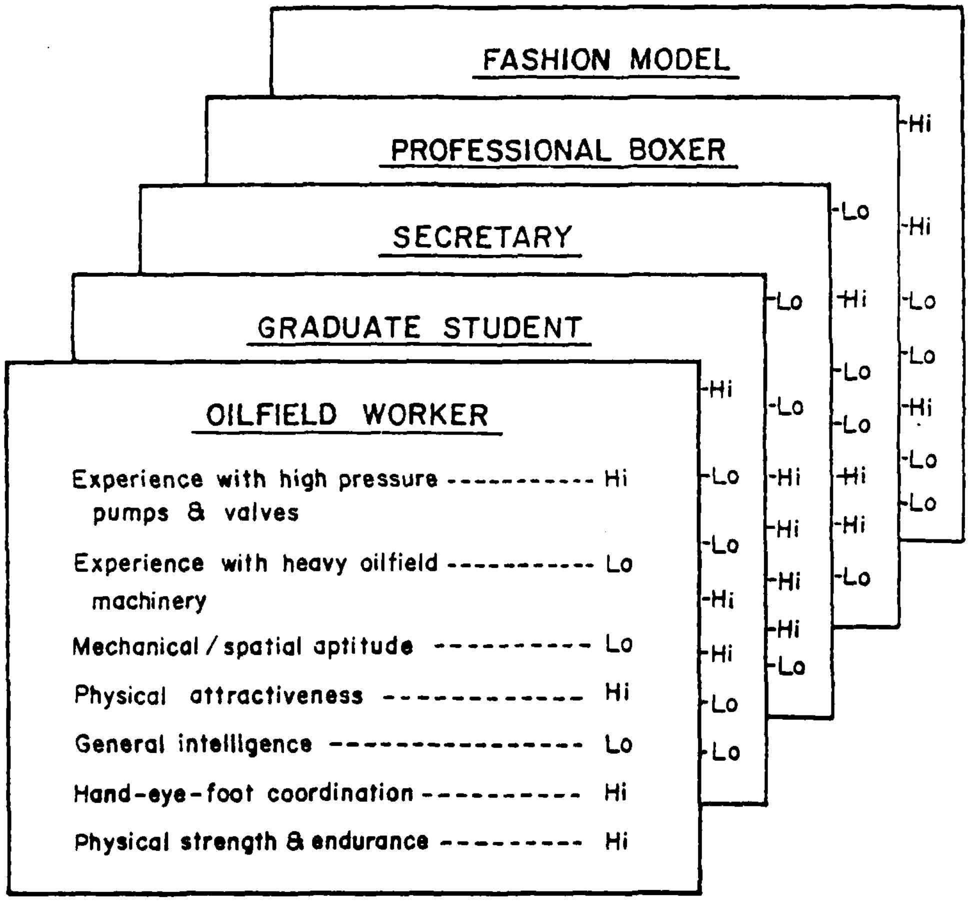

Figure 2. Illustration of the materials used by subjects to rate the suitability of hypothetical applicants for five different positions. Subjects rated 78 profiles of each type shown.

produced 0's (Lo) and 1's (Hi) in proportions prescribed by the randomly generated target proportion matrix reported in Table 3. The values on all profile dimensions were determined independently for each subject. Thus, due to sampling error, the proportion (or frequency) of "Lo" values on each evaluative cue differed slightly from subject to subject.

Procedure. In a one-hour pre-experimental session, the experimenter met with the subjects in a single group to discuss the nature of the experiment and to review the basis for their selection. Also discussed was the necessity to maintain a conscientious and professional attitude about their upcoming participation. Because the investigation involved so few subjects, the personal involvement of each was deemed essential. An excellent rapport was established between subjects and experimenter and there was a general belief among subjects that their participation was, in fact, a meaningful contribution to the further understanding of human judgment processes. The precise nature of the task (i. e. a test of the sufficiency of attention in frequency encoding) was not revealed for fear that the highly dedicated subjects would feel, in some way, obligated to prove whatever they perceived the experimenter's hypothesis to be.

The subjects met individually with the experimenter for the single three hour experimental session. Each participant was seated in a cubicle equipped with a desk, a chair and an intercom system (for communication with the experimenter). The experimenter, who was seated in an adjacent room, could also monitor the subject visually by means

TABLE 3

Randomly Generated Target Proportions of Lows (0s) Versus Highs (1s)
For the Evaluative Cues Contained in Each
Type of Hypothetical Applicant Profile

	Target Proportion of Lows (0s)						
Profile Type	Cue 1	Cue 2	Cue 3	Cue 4	Cue 5	Cue 6	Cue 7
Oilfield Worker	.53	.53	.69	.40	.63	.55	.83
Graduate Student	.73	.15	.71	.27	.26	.87	.46
Secretary	.30	.59	.51	.86	.05	.30	.41
Professional Boxer	.10	.02	.51	.77	.79	.09	.71
Fashion Model	.51	.86	.05	.30	.75	.29	.28

of a window constructed of one-way mirror. The subject was provided with five booklets, each of which contained a cover page and 78 hypothetical applicant profiles. The cover page indicated the position for which the applicant profiles were to be judged and also provided a list of the seven evaluative cues which were to form the basis for the judgments (See Table 2). The ordering of the booklets was determined randomly for each subject. The subjects were instructed to study carefully the cover page of the appropriate booklet so as to determine the relevance of each cue to the position under consideration. They were given as much time as necessary to contemplate the cues and formulate a judgment policy. After the study phase, the subjects worked through the applicant profiles, studying the (relevant) information provided in each case, and then marking an overall rating on a 10-point scale of "suitability." The pace at which they performed the rating task was controlled by an auditory signal (tone) that marked 12 sec. intervals. The external pacing was introduced to control the otherwise highly variable processing time among subjects, and (because of the brevity of the interval) to eliminate the possibility that subjects would develop mnemonic strategies for coding frequency numerically in their "spare time."

After completing each of the five profile booklets, the subject was asked to estimate the absolute frequency with which "Lo" ratings occurred on the various evaluative cues that made up the applicant profiles. The FEs were reported orally to the experimenter. The latencies associated with these estimates were recorded by the experimenter using a hand-held digital timer with centisecond accuracy. Because the experimenter was seated behind a one-way mirror, the subject was unaware that latencies were being recorded. The subjects were encouraged to take a rest break after the completion of each profile set. On the average, however, subjects took only two breaks (consisting of approximately 10 minutes each).

Results and Discussion

Before valid comparisons could be made between the distribution of attention and FE performance, it was necessary to evaluate subject performance on the hypothetical applicant rating task. To assess rating task performance, separate multiple regression analyses were performed on the five profile sets for each subject. In each case, the judgments of applicant suitability were regressed on the corresponding evaluative cue values. This procedure resulted in five multiple regression equations per subject, one for each profile type. The R^2 associated with the solutions are reported in Table 4. The tabled values clearly indicate that the subjects were indeed highly consistent in the application of their profile rating policies. An overall mean R^2 of .953 was obtained. This, of course, means that over 95 percent of the total variance in suitability judgments was explained or accounted for, by the evaluative cues. Thus, the four subjects performed excellently on the rating task.

Multiple regression analysis has often been used to model the processes by which evaluative data are aggregated. The beta weights

TABLE 4

Rating Task Performance Measured in Terms of R^2 for Each Profile Type

Profile Type	Subj. 1/	Subj. 2/	Subj. 3/	Subj. 4/
Oilfield Worker	.979	.983	.982	.907
Graduate Student	.968	.993	.991	.828
Secretary	.979	.920	.985	.958
Professional Boxer	.944	.999	.930	.805
Fashion Model	.968	.992	.998	.932
Mean	.968	.978	.978	.886

derived from the regression of judgments (or overall ratings) on cue values (or independent variables of some sort) have been interpreted as measures of cue importance in the judgments. For example, in the present study, subjects judged the suitability of hypothetical applicants for graduate school on the basis of (Hi/Lo) ratings on physical strength, general intelligence, physical attractiveness, letters of recommendation, motivation level, college GPA, and emotional maturity. Regression of the 78 suitability judgments on the 78 corresponding configurations of Hi's and Lo's on the evaluative cues would result in a solution consisting of seven beta weights, one weight for each cue.

The magnitude of the beta weight associated with each cue is a direct index of cue importance to the rater or judge (Lane, Murphy & Marques, Note 3). In the present example, a relatively high magnitude beta weight would be expected for the cue "general intelligence" while a weight of considerably lower magnitude would be expected for "physical strength" or "physical attractiveness." Other judgments which have been modelled in similar ways include the rating of livestock (Phelps) & Shanteau, 1978), teaching effectiveness (Marques, Lane & Dorfman, 1979) and the predictions of security analysts (Ebert & Kruse, 1978).

While beta weights have been used in a variety of ways, they have not been interpreted previously as an objective index of attention allocation among the cues comprising a multidimensional stimulus (or applicant profile in this case). The connection between a measurement of the _importance_ a subject attaches to a cue and the _attentiveness_ he/she accords it is, of course, purely logical. It seems reasonable to assume that in processing multidimensional stimuli individuals will attend to, monitor or track the dimensions they view as more important while minimizing the investment of cognitive resources in dimensions they consider largely irrelevant. Thus, the assumption introduced here is that there is a direct correspondence between the magnitude of a raw score regression weight (or beta weight) and the amount of attentive effort allocated to a particular cue.

The presumed relationship between cue utilization and attention allocation provides a convenient and non-intrusive method for assessing the automaticity of frequency encoding. As suggested earlier, the "automatic" view of frequency encoding would gain considerable support if a statistically reliable and meaninfgul relationship were found between cue utilization indices (i. e. indirect attention measures) and FE performance on the corresponding cues. In order to test the relationship, the subjects' FE data were converted to unsigned deviation score form. The 35 deviation scores (5 profile sets X 7 profiles per set) were regressed on the corresponding true frequency scores, raw score regression weights (or cue utilization incides), and response latency measures. Separate analyses were conducted for each subject. The results of these analyses, which are summarized in Table 5, show conclusively that cue utilization indices did not contribute in any meaningful way to the accuracy of FEs. This was true for all subjects.

Response latency was also unrelated to FE performance across all subjects. It was somewhat surprising to find that more deliberate responses were not associated with improved FE performance. Furthermore, no readily interpretable relationship was found between the true frequency of target items and response latency across the subjects. The $\underline{r}$ coefficients obtained from the correlation of true frequency with response latency were -0.059, 0.059, -0.267 and -0.221 for subjects 1 through 4 respectively. The $\underline{p}$-values associated with those coefficients were greater than .05 in all cases. It seems clear that the retrieval of frequentistic information (in realistic settings) is not accomplished by some sort of intuitive counting system that searches storage for each occurrence of a particular event. Were this the case, a relationship would probably exist between the time spent "counting" and the number of target traces entered in storage. At any rate, speculation as to the meaning of unreliable statistical relationships is unwise.

As indicated in Table 5, the <u>true frequency</u> of target repetitions exhibited the strongest relationship with FE performance. Plots of the data showed error to be a linear function of true frequency. In other words, the estimates become progressively worse as the true frequency of the target events increased. In post-experimental interviews <u>all</u> subjects spontaneously reported (a) that they had not "concentrated" on frequency information, and (b) frequency estimates were particularly difficult to make because they had no idea how many profiles they had seen. The latter observation points to the propensity for individuals to invoke sampling techniques when attempting to retrieve non-cued frequentistic information. Sampling, of course, entails the systematic or random accessing of various storage locations in an attempt to <u>estimate</u> the total number of target traces. Sampling strategies do rely upon sample size information however. Based on post-experimental sessions where subjects were encouraged to introspect and relate information about their retrieval processes, it was apparent that absolute frequency judgments were not <u>absolute</u> judgments at all. Rather, they were derived from the (a) sampling of storage, (b) estimation of sample size, and (c) the <u>intuitive computation</u> of the absolute frequency on the basis of the results of processes (a) and (b). It should be emphasized that each subject reported this information spontaneously when asked "what was particularly difficult

TABLE 5

Contributions of True Frequency, Cue Utilization and Response Latency Measures to the Obtained Variance in Frequency Estimation Performance

	True Frequency		Cue Utilization		Response Latency	
	F	P	F	P	F	P
Subject 1	63.72	.000	0.52	.475	0.12	.734
Subject 2	22.72	.000	0.04	.845	1.62	.213
Subject 3	57.00	.000	0.18	.671	0.51	.482
Subject 4	39.06	.000	0.35	.558	0.01	.912

about the frequency estimation task?" Considering the complexity of the retrieval strategies utilized by the subjects, the general lack of correspondence between response latency and target frequency should not be surprising.

The failure to find even the slightest hint of a statistical relationship between the cue utilization measures and FE performance suggests that attention per se is not sufficient for the processing of frequentistic information. The highly consistent rating task performance ($\overline{R}^2$ = .952) exhibited by the subjects left no doubt that particular dimensions in the profile data received extensive attention. Yet, ostensibly, this attentive effort was not invested in the development of high quality frequency records. It appears, therefore, that the cognitive processes involved in encoding of frequency information are considerably more complex than once recognized. The specific processing strategies involved in the transformation of repetitive data into lasting frequency records remain to be identified. At any rate, it is abundatly clear that frequency cannot be viewed as the result of an automatic mechanism or even as an incidental by-product of effortful processing that has been invested in some other task.

EXPERIMENT 3: FURTHER EVIDENCE FOR A NON-AUTOMATIC INTERPRETATION OF FREQUENTISTIC ENCODING PROCESSES

Pre-experimental instructions have been shown to affect the development of frequency records. Presumably, instruction operates to focus attention on the repetitive characteristics of incoming data which, in turn, activates specific processing strategies that result in reasonably accurate frequency records. Unanswered in the research concerning instructional effects is the question of whether the observed improvements in FE performance is gained at the expense of degraded performance in other ongoing cognitive activities (e. g. the rating of hypothetical applicant profiles). Substantial degradation in the concurrent task performance would suggest that whatever processes are governing frequency representation, they draw upon a limited capacity afforded by attention. Were they instead "automatic," and therefore not capacity demanding, they should not affect the rating performance adversely. Thus a search for performance tradeoffs would yield important information on the automaticity of frequentistic encoding operations.

The purpose of Experiment 3 was to assess the automaticity of frequency encoding by way of a dual-task paradigm in which an obviously non-automatic task (i. e. hypothetical applicant rating) was paired with a standard FE task.

Method

<u>Subjects</u>. The four practiced subjects from the previous experiment

returned for participation in Experiment 3. Once again, the subjects received $5.00 per hour for the study which lasted approximately two hours.

Task and Stimuli. The overall task scenario was quite similar to the one employed in Experiment 1. Again, two tasks were devised: a rating task involving selection of candidates for a federally-funded training program, and a frequency task that required monitoring specific dimensions of candidate profiles (e. g. how many females?). The expenditure of effort on the tasks was manipulated through instructions in much the same way as it was in Experiment 1. The subjects viewed 20 blocks of profiles consisting of 20 observations each. Instructions specified that the rating task was of primary importance for 10 profile blocks; the frequency estimation task was of primary importance for the remaining 10 blocks.

For the rating task, good performance was defined primarily in terms of the consistency with which the four dichotomized profile cues (male/female; black/white; physical handicap....yes/no; criminal record....yes/no) were aggregated in the assignment of "candidate acceptability" ratings.

In the FE task, subjects were required to estimate the number of females, blacks, handicapped and former criminals represented in each block of 20 profiles. Each of these targets occurred with frequencies of 0, 2, 4, 8 and 16 in four separate blocks, twice in the 10-block series where the rating task was primary, and twice in the 10-block series where the FE task was primary. The placement of the five frequency levels within each 10-block series was determined randomly and independently for each of the four targets.

After the FE task was completed for a given block, the subjects were given a straight-forward memory task in which the object was to recall the serial position of the targets that had appeared with a frequency of 2. The 20-profile sequences were broken into quadrants and the subject was required to identify the quadrant number(s) in which one or more of the targets appeared. It is important to note that this procedure was followed for all targets in which the true frequency was two, regardless of the subject's estimate.

The physical appearance of the candidate profiles is shown in Figure 3. Once again, the profiles were arranged to facilitate the rapid encoding of all critical information.

Procedure. The subject was seated in a cubicle and presented with a prepared text that discussed the nature of the federally-funded training program for which the hypothetical candidates were to be considered and reviewed the basic mechanics of the dual-task paradigm. For half of the subjects, the order or primary tasks was FE-rating, while for the other half, the order was rating - FE. The subjects who received the latter ordering were first read:

> Until I tell you otherwise, the rating task is, by far, the more important task. Do as well as you can on the frequency task but do not, under any circumstances allow your performance on the rating task to slip. Do not be concerned if you cannot provide accurate frequency judgments. We want you to concentrate on rating the profiles as consistently and conscientiously as you possibly can at all costs! Rating consistency is very important. Frequency judgments are not important. Please follow these instructions.

The subjects in the rating - FE conditions heard virtually the

APPLICANT NO. 12

SEX ------------------------ FEMALE

RACE ------------------------ BLACK

PHYSICAL HANDICAP ------------------ NO

CRIMINAL RECORD ------------------ YES

Figure 3. Illustration of an hypothetical applicant profile used in the performance of two tasks, frequentistic coding of all stimulus dimensions and aggregation of these cues to produce a set of consistent judgments of applicant acceptability for a job-training program.

same plea again before the beginning of the second 10-block sequence; the difference was, of course, in the emphasis of the FE task over the rating task. Subjects in the FE -rating condition received the identical instruction sets in the opposite order.

After all instructions were given and all questions answered, the subject was seated in front of a TRS-80 microcomputer which controlled the display of the stimulus materials. The profiles were presented on a CRT for 3.0 sec. followed by a blank screen for 1.5 sec. during which the subject recorded the ratings on the response form supplied. After the completion of a profile block, FEs were obtained for each of the four target events. The target localization task followed the FEs. The request for and response to the FEs and target localizations were made verbally. It was felt that this method would help to maintain a higher level of conscientiousness on the part of the subject. Of course the experimenter was seated behind the subject to avoid the possibility of unwanted, non-verbal feedback of some sort. This procedure was followed for the first 10 profile blocks. A 5-10 min. rest break was given after the completion of the first 10-block series. After the break, the subject returned to work on the second 10-block series in which the status of each task was reversed from its previous level.

Results and Discussion

As expected, the overall quality of FE performance was superior when it was the primary task. The mean unsigned error scores (and standard deviations), collapsing across subjects, were 1.431 (.664) and 2.256 (.890) for primary status and secondary status respectively. This was a reliable finding, $\underline{F}$ (1,3) = 11.363, $\underline{P}$ = .043. Subjects tended to improve their performance over profile blocks although the effect only approached statistical significance, $\underline{F}$ (9,27) = 2.068, $\underline{P}$ = .070. Also, the quality of FE performance was not appreciably different across the four target events, $\underline{F}$ (3,9) = 2.475, $\underline{P}$ = .128. The mean unsigned deviation scores for primary and secondary FE status are shown in Figure 4 for each of the subjects. The Figure illustrates the consistency of the effect of task status on the quality of FE performance.

The incidental target localization task was included in the present paradigm with the hopes that it would provide information regarding possible differences in the representational form of the frequency information which were related to the status of the FE task. Obviously, one way that FE performance could benefit from the special processing prompted by the "primary status" designation is through the introduction of some change in the manner in which frequentistic information is held in storage. For example, a multidimensional stimulus, such as an applicant profile, might be broken down into its individual dimensions, which are then coded and stored separately. At any rate, superior recall of specific event occurrences would be expected under conditions of primary FE task status. The results of the test of this hypothesis are summarized in Table 6. "Hits" were registered when two conditions were met: first, subject correctly estimated the true target

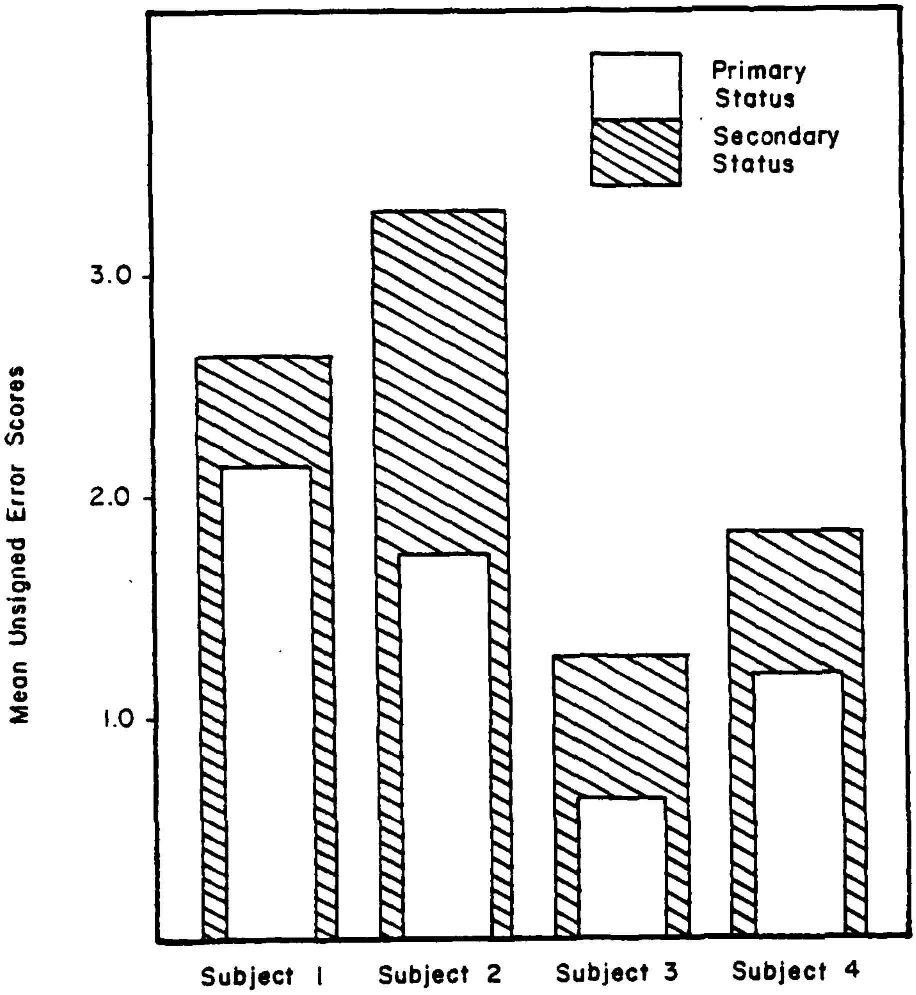

Figure 4. Frequency estimation performance of each subject measured in both primary and secondary task status conditions.

TABLE 6

"Hits" in Target Localization as a Function of Frequency Task Status

Subject	Primary Status	Secondary Status
1	2	0
2	0	1
3	5	4
4	0	1
Total Hits	7	6

frequency (i. e. 2 in all cases) and, second, when the subject identified the quadrants in which the target events appeared. Given that the first condition was met, the probability that a subject would correctly identify the item locations by chance was .125 or 1 in 8. Because eight localization responses were elicited in each of the status (10 blocks) conditions chance performance would be a score of "1" for both the primary and secondary FE task status. As apparent from Table 6, only Subject 3 performed at a level appreciably higher than chance. The performance level exhibited by Subject 3 was uniformly good across both status conditions however. Clearly, these findings do not eliminate the possibility that individuals code and store frequentistic information in a variety of ways, depending on the perceived importance of accurate FEs. They do, however, reinforce the notion (introduced previously) that the particular cognitive processes associated with frequency are far more complex than realized. The dismal performance on the target localization task may also reflect the use of very different processing strategies.

Because of the processing demands of the secondary task, and the short exposure duration of each profile, it was impossible to code the frequency information numerically, even when it was primary. Post-experimental interviews revealed that subjects compensated for the inability to count by the use of data simplification strategies. While the details of the strategies were largely idiosyncratic, one commonality surfaced. Subjects reported collapsing or "chunking" applicant profiles into meaningful groupings of attributes. For example, subjects usually maintained "counts" of black females, handicapped females, white former criminals, or some such combination. When asked about the frequencies of particular events, individuals would have to assemble the information from a variety of memorial sources. Put simply, there was no evidence whatsoever, either from the empirical findings or the introspective reports, to suggest that the frequency with which each stimulus dimension (or target) appeared was catalogued separately in storage. It follows that the temporal or serial positions of individual profile dimensions would also be largely inaccessible to retrieval operations.

It has been demonstrated that FE task performance was superior in the primary status condition. The principal question now concerns whether a performance tradeoff existed in the joint performance of the FE and rating tasks. Was, for example, improved performance on the FE task gained at the expense of reduced performance on the rating task, and vice-versa?

To address this question, a measure of rating task performance was developed. The first step in this procedure was to perform an odd-even split of the 200 (10 blocks X 20 profiles per block) profiles rated in each status condition. Multiple regression analysis was performed on the odd profiles contained in each condition separately. Thus, two separate multiple regression equations were formed for each subject: one equation reflecting primary status rating behavior, and one equation reflecting secondary status rating behavior. The raw score regression weights obtained from these procedures were then applied to the cue values associated with the 100 even-numbered profiles in the respective status conditions. The resultant predicted ratings were then correlated with the obtained profile ratings, thereby yielding a measure of consistency in rating performance ($r\ \hat{y} \cdot y$) which was ammendable to statistical significance testing. In all, eight $r\ \hat{y} \cdot y$ measures were computed, one measure of primary status consistency and one measure of second status consistency for each of the four subjects. These values are presented in Figure 5. All subjects showed a marked decline in rating performance when the task was relegated from primary to secondary status. In fact, the decline in Subject 2 performance was so drastic that it was not reasonable to expand the scale in Figure 5 to accommodate the secondary r $\hat{y} \cdot y$ value. The primary and secondary r $\hat{y} \cdot y$ scores from Subject 2 were .952 and -.058 respectively. The obtained differences between primary and secondary rating task performance were statistically significant for all subjects; the Fisher's $\underline{z}'$ transformation values (and associated $\underline{p}$-values) were 2.138 (.032), 12.981 (.000), 3.078 (.002) and 2.284 (.023) for subjects 1 through 4 respectively.

The expected performance tradeoff between the concurrent tasks of FE and profile rating was found in Experiment 3. Recall that Hasher and Zacks (1979), Posner and Snyder (1975), Shiffrin and Schneider (1977), among others, have argued that "automatic" cognitive processes do not interfere, or interfere minimally in the performance of other ongoing activities. A pronounced interference was documented in Experiment 3. Not only does this fail to disconfirm the non-automatic view of frequentistic information processing, it strongly suggests that the concurrent tasks competed, to some extent, for the same limited pool of cognitive resources. The subjects were not told to ignore the secondary task, they were told to do the best they could without allowing primary task performance to decline. Therefore, were it possible to achieve quality performance on both tasks, it would have been done. The fact that quality joint-performance was not achieved implies that the limited capacity allocated by attention was exceeded by the aggregate resource demands of the two tasks.

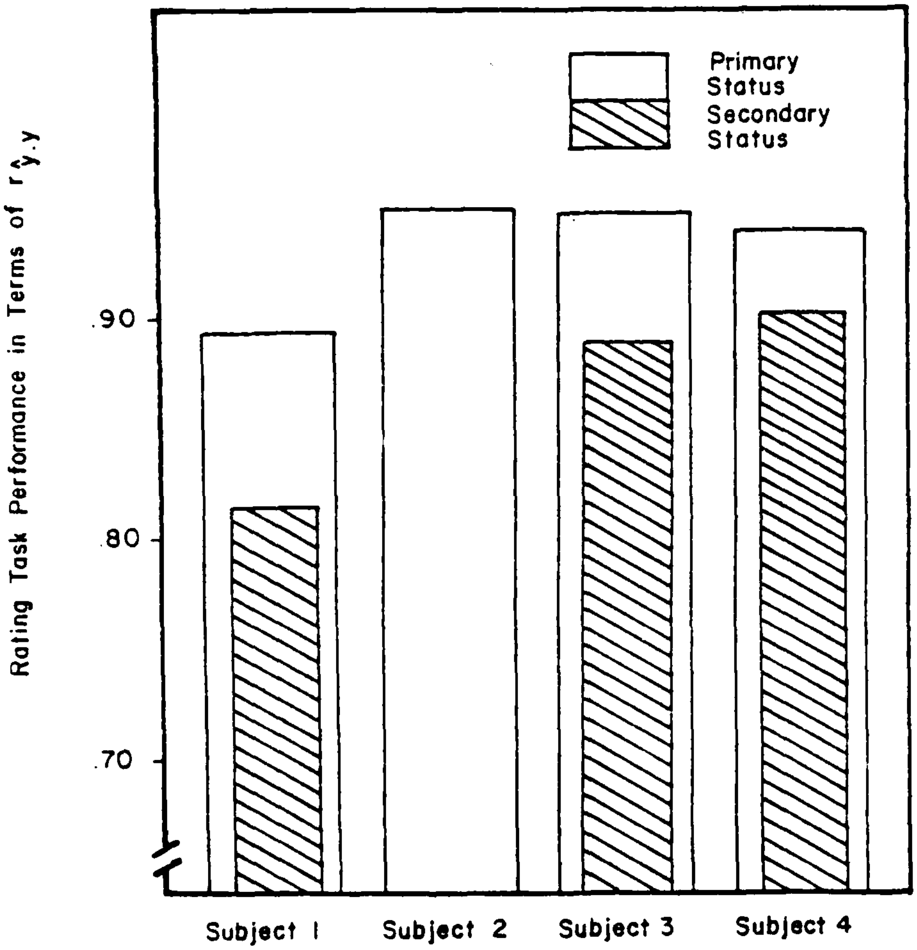

Figure 5. Rating task performance of each subject measured in both primary and secondary task status conditions. For Subject 2, rating task performance in the secondary status condition ($r\ \hat{y}\cdot y = -0.058$) was too extreme to warrant inclusion on the otherwise appropriately scaled graph.

GENERAL DISCUSSION

The vast majority of day-to-day choices, predictions, and judgments are preceded by the retrieval of pertinent information from storage. This information may be conceptualized as an intuitive data base that is composed of numerous decisional elements. Most investigations of human decision making have focused on the processes by which these decisional elements are transformed (i. e. integrated, aggregated, etc.) in producing decisions or judgments of some sort. Little concern has been given to the processes by which these elements are encoded and retained in storage. This general lack of concern has placed severe constraints on the ability to comprehend a great many individual- and task-related differences in decision making.

The present paper has been concerned with some of the processes associated with the information and retention of decisional elements. Information about the frequency with which events occur constitutes an important element in a variety of <u>real-world</u> decisions, preferences, attitudes, beliefs and so on. Consider the common industrial/organizational concerns of employee motivation and job satisfaction. It is generally held that employees, in as much as possible, choose to invest the most effort in those aspects of their jobs that are associated with the greatest extrinsic and intrinsic rewards (Lawler & Suttle, 1973). There is a significant frequency component underlying perceptions of the instrumentality of various job behaviors for the attainment of desired rewards. An assistant professor may attempt to infer a promotion board's policy for weighting teaching quality and research activity by estimating the frequencies with which various levels of joint performance had resulted in promotion for his/her colleagues or acquaintances. It is clear that the veridicality of the stored frequency records could be a contributing factor to the success or failure of the candidate if the records resulted in a decision as to how effort should be distributed between the functions of teaching and research.

Despite the importance of frequency information, the associated cognitive processes are not well understood. One reason is, of course, that frequentistic information processing is extremely difficult to study. The primary reason is that often when subjects realize the "true nature" of the study, their information processing strategies change markedly. This gets back to the notion of propositional encoding where subjects allocate attentive effort and direct various controlled processes on the basis of "hunches" regarding the purpose of the study. Another reason is that numerous investigations have been conducted with the intent of identifying <u>the</u> true frequency mechanism, or <u>the</u> true representational mode of repetitive information. If anything has been learned from the present series of studies, it is that the search for unitary mechanisms, or unitary representational forms is not likely to be very productive. Sensitivity to frequency is not the result of a unitary encoding mechanism or representational form. Rather, as suggested earlier, it is the result of complex interplay among special controlled processes that shape and channel the flow of repetitive information into forms which are ammenable to frequentistic retrieval operations. Of course, retrieval operations are also subject to controlled processing (Jacoby & Craik, 1979). In Experiment 2 and Experiment 3, extensive post-experimental interviews revealed a vast array of esoteric encoding and retrieval strategies. Apparently, the facilitation of retrieval does not necessarily mean semantic encoding, or counting, tagging and so forth. There exists an entire system of frequency encoding and retrieval options. The particular options invoked in processing a given frequentistic event stream appear to depend first upon the availability of cognitive resources (Norman & Bobrow, 1975) or processing capacity (Johnson & Heinz, 1978), and second upon a variety of individual and task-related variables.

One criticism of most previous research in the area of frequency has been that, for the most part, only simplistic and highly artificial experimental stimuli have been used. Obviously, there is nothing inherently wrong with using stimuli of this nature except when attempting to generalize to how individuals process repetitive information in the real world. For example, few would argue that frequency records for random digits presented 2 per sec. are maintained in the same manner as frequency records for Presidential blunders distributed over a period of four years. For in the real world, information simply is not perceived and processed in quite the same manner as it is in the laboratory. Prior beliefs, expectations and a host of judgmental biases operate in the allocation of attention and the resultant activation of special controlled processes when individuals attempt to code and store various dimensions of real world repetitive events. These crucial processes cannot be seen in most laboratory investigations because there is rarely any uncertainty about what information should be attended to, or how it should be encoded. Therefore, it appears that use of highly simplistic stimuli does not yield simplified representations of real-world frequentistic information processing but qualitatively different representations. Therein lies the danger of artificiality.

In the present series of studies, some measure of progress was gained toward the development of a realistic and yet experimentally sound task environment for the study of frequentistic information processing. Clearly, however, there is a long way to go. Nevertheless it is encouraging to note that there was some degree of convergence in the findings of this series with investigations which were more basic in emphasis and investigations which were more applied. For example, the finding in Experiment 2 that individuals were generally poor in absolute FEs when the task was secondary and when sample size information was unavailable was similar to the findings of Lichtenstein et al. (1978) and others who have reported that a number of judgmental biases and sampling techniques enter into the estimation of real world frequentistic events. Yet, under optimal encoding conditions, such as in the primary status condition in Experiment 3, excellent FE performance was achieved. This finding was consistent with those of many investigations that were more basic in emphasis (e. g. Erlick, 1961; Hintzman, 1969).

Recall that the goal of this series of investigations was to provide a convincing test of the automaticity of frequentistic encoding operations. As expected, the data strongly support the notion that sensitivity to frequency is the result of special or strategic conscious, controlled or effortful processes afforded by the allocation of attention. But what has been gained here is largely "surface" information. It can be said that special controlled processing must be involved if quality frequency records are to develop. But little is known about precisely how and when controlled processes are activated.

The next logical step in this area of research might involve the identification and description of various types of controlled processes. It may be that there are individual <u>and</u> data-induced differences in the manner in which frequentistic information is processed. The development of a general taxonomy of frequentistic encoding and retrieval operations may lead to an understanding of if and when certain controlled operations are more effective than others. Ultimately, the goal would be to explain why some individuals are superior at frequency related decision tasks and how these "skills" may be acquired by others.

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